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TRINITROTOLUOL.

PRACTICAL POINTS IN ITS SAFE HANDLING.[1]

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The great reduction in individual efficiency, the lost time, the ill health, and the sometimes fatal results due to chronic poisoning from the nitro and amido compounds of benzol and toluol in general, and trinitrotoluol in particular, are now so well known, and the danger of the occurrence of cases of such poisoning in the tremendously developed munitions industry is so manifest, that there can be little doubt that attempts will be made by all firms engaged in handling such poisons to safeguard their workers from chronic poisoning.

The safe handling of trinitrotoluol, however, can not be accomplished by the will to prevent poisoning alone. Poisonous compounds like trinitrotoluol can only be handled with safety to the workers concerned provided strict attention be paid to a considerable number of details, each of which is perhaps but a small component factor in the defense, the integrity of which, nevertheless, depends upon its unbroken front. This paper, therefore, is an attempt to summarize the practical means for securing effective prevention of poisoning by trinitrotoluol.

Channels of poisoning.—It is well known that trinitrotoluol, like many of the other nitro and amido coal-tar compounds, is readily absorbed through the skin. The next important avenue of absorption is the respiratory tract. Trinitrotoluol is absorbed with much more difficulty through the mucous membrane of the intestinal tract. The main channel of excretion is probably the urinary tract, although it is possible that a certain amount may also be excreted through the intestines.

Like all other poisons, there is a minimum toxic dose, which varies according to the susceptibility of the individual. As long as the amount absorbed remains beneath these limits symptoms will not be observed. While it is well-nigh impossible to prevent completely the absorption of trinitrotoluol whenever this substance is handled, nevertheless it is quite practicable, by attention to the points presently to be discussed, to keep this absorption well below the minimum toxic dose, except, perhaps, in the case of susceptible persons.

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[1] Read before the section on industrial hygiene of the American Public Health Association, Washington D. C., Oct. 18, 1917.

The following remarks are confined solely to the processes involved in the loading of shells with trinitrotoluol, for the reason that its manufacture is mainly confined to a few firms, whereas loading processes are likely to be carried on by any manufacturer possessing the requisite facilities, which, after all, are rather simple. For this reason the number of workers involved in loading operations is likely to be very much greater than that concerned in the manufacture of this substance. Besides this, long contact with the production of other poisonous nitrated benzol products should have given manufacturers of trinitrotoluol the requisite experience to enable them to handle the manufacture of this substance with safety to the workers concerned. In addition to this, in the manufacture of trinitrotoluol, except at the final sieving and packing operations, the substance is handled either in closed containers or in a moist condition, under which circumstances the risk of poisoning is very greatly reduced. In loading operations, on the other hand, there is constant opportunity for nearly everyone connected with such work to become the subject of chronic poisoning through either the fumes or the dust of this substance.

Precautions to be Observed.

If it is desired to reduce the risk of poisoning with trinitrotoluol to a minimum, attention must be paid to certain details under the following general headings:

1. Planning and construction of workrooms.
    (*a*) Separation of processes.
    (*b*) Conveyor systems.
2. Methods and processes employed.
3. Sanitary precautions on the part of the workers.
4. Hours of labor.
5. Medical supervision.

Planning and construction of workrooms.—The planning and construction of buildings used for handling trinitrotoluol can either greatly simplify or complicate the problem of its safe handling. There is no doubt that great advantage, so far as both production and safety to the health are concerned, is derived from correct location of buildings in relation to each other, the general principle being that these should permit continuous routing of the raw materials so that at no point are there any crosses in the route of the product as it proceeds from the raw to the finished state. This permits the complete segregation of one stage in the process of loading from another, and prevents the exposure of one set of workers to hazards derived from a process with which they have nothing to do.

Type of buildings.—The type of buildings in which a dangerous substance like T. N. T. is handled has also much to do with the facility with which sanitary conditions may be obtained. All such buildings should be long, narrow, and of one story. Such construction lends itself readily to the installation of the conveyor system and methods of progressive assembly; abundant natural ventilation is readily furnished because of cross currents of air through opposite openings. Moreover, monitors in roofs in conjunction with the side openings will operate more effectively than similar installations in rooms which are approximately square. Another favorable characteristic of a long and narrow construction, which aids in the maintenance of sanitary conditions, is the abundant natural illumination afforded. This not only facilitates the work, thus preventing unnecessary splashing and spills, but a well-lighted condition in a workroom reveals accumulations of dust and dirt which otherwise lurk unnoticed.

Separation of processes.—A fundamental tenet in all hazardous processes is that the only persons exposed to the particular hazard should be the group of workers involved. The long narrow construction of buildings renders the segregation of various processes easy by the use of cross partitions. With the square building, this is much more difficult to secure. Such partitions cut off needed light, the greater length makes them expensive to erect, the necessity for using all the floor area either renders their erection impracticable, or if erected, disturbs the routing of the material.

Conveyor systems.—There can be no question that a properly installed conveyor system greatly facilitates the safe handling of trinitrotoluol in loading operations, because handling the substance in the shells is reduced to a minimum. Again, as previously pointed out, such conveyor systems are much more readily installed in long narrow buildings than in square buildings.

Methods and processes involved.—There are two general ways in which the explosive is introduced into the empty shell. The powdered trinitrotoluol may either be pressed into the shell by power presses, or poured into the shell in a molten condition.

The former process is used mainly for loading large shells, which of course are used in much less quantities than small shells, in military operations. Moreover, presses are installed in heavy concrete compartments to guard against the effects of possible explosions. Very simple precautions are all that are needed to prevent any escape of dust in handling the powdered trinitrotoluol prior to pressing the charge.

In the average loading plant, however, we find that the charge is usually placed in the shell by pouring it in in a molten condition. Because of the ease with which poisoning may occur when handling melted trinitrotoluol, the following deals especially with the methods for rendering such handling safe.

Precautions in melting trinitrotoluol.—The melting of trinitrotoluol is carried on, as a general rule, in large iron kettles heated by steam coils. Such melting kettles should be installed in a separate compartment, provided with abundant natural ventilation, through opposite openings, a monitor roof, and mechanical exhaust in the neighborhood of each kettle. Such kettles should be preferably broad and somewhat shallow in form, rather than narrow and deep. The kettles should be covered in, and provided with an exhaust pipe in which a gentle upward draft is maintained by mechanical means, so that at all times a slight negative pressure exists in the kettles. This prevents the escape of trinitrotoluol fumes into the air of the melting room. The heat should be applied to the lower portion of the kettle rather than uniformly over its area. This brings about the melting of the charge from below upward, so that the trinitrotoluol at the top is distinctly at a lower temperature than that at the bottom. In this way the amount of fumes which must be gotten rid of by the exhaust is substantially less. Attention should also be paid to the temperature maintained in the kettles, so that this is not unnecessarily high. The application of too great a degree of heat in melting not only increases the loss by evaporation of valuable material, but also increases greatly the amount of fumes which may be present in the air of the melting room.

In charging the kettles with fresh trinitrotoluol, attention should be paid to the prevention of dust. The aperture in the kettle should be provided with a lip to prevent spilling of the powder. A removable hopper fitting tightly into the aperture would also assist greatly in the prevention of unnecessary dust. The installation of permanent hoppers above each melting kettle, provided with a cut-off, also merits consideration, as a large quantity of the explosive could be placed in the hopper at one time, and then gradually added in small quantities to the melting kettle as needed. In this way the exposure to trinitrotoluol dust would be reduced to a minimum.

Casting.—After the trinitrotoluol has been melted in the kettle, it is usually drawn off in tubs, in which it cools, while being continuously agitated until near the point of solidification, whereupon it is poured into the shells. The purpose of the agitation is to secure uniform and more rapid cooling of the melted product. Very often this agitation of the melted trinitrotoluol is carried on by the use of wooden hand paddles by workers who sit continuously at these tubs, doing nothing else. Obviously this is extremely hazardous, as the trinitrotoluol is constantly above the temperature at which volatilization takes place. Where this process of hand agitation is carried on, an attempt is usually made to reduce the risk of poisoning by the installation of exhaust hoods over the tubs. Personal observations, however, have led to the conclusion that hand agitation of melted trinitrotoluol can never be made safe; that the only permissible method is the use of mechanical agitators over hooded tubs. All workers seen engaged in the hand agitation of melted trinitrotoluol have presented a uniformly bad appearance.

Pouring in the shells.—Two methods are in general use. The first consists in arranging a large number of shells in racks on the pouring floor. The pourer takes a considerable quantity of the melted trinitrotoluol in a spouted container, and walks along the rows of shells filling each one as he comes to it. This method is inherently bad. In order to fill an adequate number of shells at one pouring, the pouring container is large, and when full, necessarily heavy. This leads to awkwardness and inaccuracy in pouring the charges, especially in the first shells, thus causing numerous splashes of the trinitrotoluol on the exterior of the shells, the floor of the casting room, the shell racks, and the person of the pourer. In plants where this method of pouring is carried out, the writer has seen thick incrustations of trinitrotoluol on all the localities mentioned, the overalls of the pourers especially being fairly caked with trinitrotoluol. Such methods not only greatly increase the risk of poisoning, but are wasteful of valuable material. Such wasteful methods, however, spring originally from poor design of buildings, as this is about the only practicable method in workrooms of square construction.

The only casting method which should be considered is the one in which the shells are placed in racks on a conveyor and passed before the pourer, who is stationed at the cooling kettle. There is no danger in this position to the pourer if the cooling kettle is adequately hooded with exhaust ventilation and provided with a mechanical agitator. It is needless to say that the charge in the cooling kettle should be conveyed by gravity from the melting kettle above, the opening in the cooling kettle being situated in its lower part, so as to avoid splashing of trinitrotoluol while the charge is running in. The proximity of the pourer to the cooling kettle permits the use of a small pouring ladle. This enables the charge to be accurately poured into the shell, because of the light weight handled.

Avoiding splashes on exterior of shell.—It is evident that all splashing of the explosive on the exterior of the shell should be avoided. Such splashing is not only wasteful of material, but increases the risk of poisoning in subsequent handling, as naturally all such deposits must subsequently be scraped off. Such splashing on the exterior of the shell may be reduced to a minimum by the use of the conveyor system and a small pouring ladle. As an additional precaution, however, the adapters, which are screwed into the shell orifice to protect the screw threads of the shell from being clogged with melted trinitrotoluol, and also to hold the spout through which the charge is introduced into the interior of the shell, should be provided with a perforated square of tin or stiff paraffined cardboard, slipped over the spout to catch any splashes which would otherwise be deposited on the exterior of the shell. With careful work it is quite possible to pour charges into shells without any splashing of the exterior. Wherever such methods are used the personal appearance of those engaged in pouring is all the evidence that is required to convince the observer of the superiority of such methods.

Recessing the charge.—After casting, the charge is recessed for the reception of the "booster charge" of a more sensitive explosive, required for the detonation of trinitrotoluol. The end of the charge must also be surfaced. This is usually accomplished in special drill presses. In drilling out the charge, naturally considerable dust is produced from the boring. There is also danger of a possible "blowing" of the charge. For this reason the recessing of such charges should be carried on in completely inclosed compartments, provided with doors which may be automatically opened and closed, and with the provision of some holder or jig to hold the shell in the drill press. When carried on under such conditions, workers operatting these drilling machines are exposed only to a minimum extent to any danger of poisoning.

The remainder of the operations concerned consists mainly in blowing out dust remaining after the boring, inspecting the shells, introducing "booster charges," capping the shell for shipment, and painting the exterior when this is required by the specifications.

After casting and recessing the charge the degree to which workers are exposed to trinitrotoluol poisoning will depend upon the care with which these processes have been carried out, such subsequent exposure being due for the most part to scraping off deposits from the exterior of the shell and cleaning out the screw threads in the nose or base of the shell, according to its type, from any trinitrotoluol which may be adherent. The quantities of the poison involved are naturally dependent upon the care which has been employed in the foregoing operations.

Additional operations which bring the workers in contact with trinitrotoluol consist in the recovery of trinitrotoluol which adheres to adapters and casting spouts, and the squares of tin or pasteboard which may have been used to catch splashes during pouring. Besides this, dust from the floor of workrooms and from borings is gathered up for recovery. Charges must also be recovered from shells which have failed to pass the inspection. Such recovery is simple and may be carried out safely by simple melting operations in appropriate melting apparatus, in which the general principles described in the primary melting of trinitrotoluol are complied with. There is no doubt that the recovery of trinitrotoluol from sweepings, which is usually attended to by ordinary laborers, is frequently accompanied by poisoning, as such employees are usually the least intelligent in the plant and are likely to be careless. Due attention, however, to the loading methods previously described reduces such need for sweeping to a minimum. Whatever sweeping is necessary should be done by moist methods, all sweepings being deposited in fiber or tin paper-lined boxes, with close-fitting covers. The collection of dust from boring machines in tin or fiber boxes provided with a tight-fitting lid, which may be closed subsequently, will also reduce exposure to a minimum. If tin boxes are used these should be paper lined.

Sanitary precautions on the part of the workers.—A lively sense of the poisonous qualities of trinitrotoluol and the will to prevent poisoning by the requisite cooperation with the management are necessary on the part of all the workers. This means that all workers should receive instructions from the plant officials as to the methods by which trinitrotoluol poisoning may be avoided. These consist obviously in reducing personal contact to the fumes and dust of this substance to a minimum. There is no evidence that females are more susceptible than males, but the young of both sexes are likely to be highly susceptible. For this reason persons less than 21 years of age should not be employed in processes in which the worker is brought into contact with trinitrotoluol.

A complete suit of overalls, fitting closely at the neck, wrists, and ankles, gloves, and a cap covering the hair, should be worn by all the workers. Men should keep their hair short and be clean shaven. The overalls should be provided with drawstrings at the neck, wrists, and ankles. The wristband of the overalls should be pulled over the glove gauntlet, and a snug fit secured by the use of a drawstring. Overalls should be laundered weekly. There should also be provided change and locker rooms with lockers or other facilities of such nature that the street and working garments do not come in contact with each other or with those of others.

The eating of lunches in workrooms and keeping of food in workrooms should be rigidly prohibited. Compliance with this rule is best secured by providing attractive and commodious eating rooms for the use of the workers.

The workers should be especially instructed concerning the value of scrupulous bodily and oral cleanliness, as a prevention of trinitrotoluol poisoning. The hands and face should be thoroughly washed and the mouth rinsed out before eating, and a full shower bath taken at the close of the day's work. Proper facilities for this should be furnished. The teeth should be brushed twice daily with a soft toothbrush and a good dentifrice.

One of the chief difficulties in avoiding poisoning is the reluctance on the part of workers to report to the company physician when they begin to feel sick. This is due to the relatively high wages which are paid to the workers who load ammunition and the natural desire to keep on earning these wages as long as they are able to stand up. Much of this can be done away with by a system of rotation of jobs, workers being transferred from hazardous to less hazardous employment regularly at intervals of two weeks.

Hours of labor.—Except in an emergency no person engaged in a process in which trinitrotoluol is handled should work longer than eight hours a day. By thus limiting the time of exposure, the danger of poisoning may be materially reduced. As previously stated, workers engaged in hazardous processes should be rotated to less hazardous jobs at least once in every two weeks, and oftener if necessary.

Medical supervision.—An efficient system of medical supervision under the direction of a competent physician must necessarily be provided in all plants engaged in the manufacture and handling of trinitrotoluol. The physician in charge should be familiar with the symptoms of poisoning and the precautions for preventing it. He should keep a constant check upon the efficiency of the enforcement of sanitary precautions and be given the authority to transfer or to lay off, as may be required, all workers who are showing symptoms of poisoning. He should also make frequent rounds of inspection through the workrooms, noting all workers showing the characteristic appearance of trinitrotoluol poisoning, and requiring them to report to the works dispensary for further examination. Careful records should be kept of all cases of poisoning and their subsequent treatment.

TYPHOID FEVER SPREAD BY CHRONIC CARRIERS.

A REPORT OF SEVERAL SMALL OUTBREAKS OF WHICH THREE WERE MILK BORNE.

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In order to emphasize the importance of the typhoid carrier in the distribution of the infection through the handling of food we have thought it might be of interest to add the cases which follow to the literature of this subject, and we shall first briefly describe a milk-borne epidemic in which the typhoid bacillus was isolated from the stool of a typhoid carrier on the dairy farm and also from the milk which produced the outbreak of typhoid fever.